Summary of and Responses to ESP Project Reviewer Comments

An Enzyme Sugar Platform (ESP) project interim gate review meeting was held on May 1-2, 2003 in Golden, Colorado to review progress and solicit input from external reviewers and meeting participants. The comments are grouped into four general categories of project management, ESP core research, process analysis, and future directions.

Project Management

General

Summary Comments: The reviewers agreed that the ESP's original purpose to provide a placeholder for an industry-led project in the context of stage gate project management has been successful and that the project should continue forward as a research-track project either in Stage B or C. There was some concern from other participants regarding the cellulase cost target in that, the enzyme producers have achieved the 10-fold cost reduction, but the enzyme manufacturers projected current cost of enzyme is $0.30 to $0.50/gal, while the program's target is $0.10/gal.

Responses:

- We agree that the project should be defined as a research-track project and recommend that the ESP project now be considered a Stage B project (Research Development). In this role, we will provide support and work on technologies that facilitate commercial track projects, specifically, the recently awarded Bioenergy solicitation winners.

- The cost of enzyme established at the beginning of the subcontracted effort after input from the enzyme manufacturers was higher than previous estimates made in the late 90's. Therefore, additional cost reductions will be required to achieve the target enzyme cost goal of $0.10/gal.

Project Management

Summary Comments: The reviewers thought the project did not appear to have well defined tasks with specific deliverables and due dates.

Responses:

- Although the overall goal of the project is well known, the implementation of long-range plans is being coordinated with Bioenergy solicitation awardees. Information from this effort along with the FY04 Annual Operating Plan (AOP) and the Multi-Year Technical Plan (MYTP) drafted by the Biomass Program provide the project with specific goals, deliverables, and due dates for the coming years. The major milestone is to complete a limited pilot scale demonstration of integrated processing and to use the process performance data to validate (or update) process economic modeling assumptions by 2006. Interim milestones are: 1) demonstrate reliable compositional analysis methods and accurate pretreatment yield measurement (defined as achieving a C-balance

closure of 95% across pretreatment) by 2004; 2) achieve high-yield high solids pretreatment (defined as 85% hemi yield and 90% enzymatic digestibility at 30% solids) by 2005; 3) Demonstrate integrated processing in 2006, with the minimum goals here being to run the process for 1 week (24/7) at the 1 ton/day process scale.

Communication/Outreach

Summary Comments: The review panel suggested that the review format be changed to allow more frequent interaction and direction from industry. This could include more frequent review meetings with more interaction between industry participants and NREL researchers (discussion format that might include voting and prioritization by a larger industry group), as well as conveying results to interested parties on a regular basis.

Responses:

- We are evaluating potential changes to the review format along with the possibility of developing a regular means of communication in consultation with DOE. These issues will be discussed at the next stage gate review meeting tentatively scheduled for August 2004. In the meantime, a document highlighting recent events and research progress in the ESP project will be made available to interested parties on a quarterly basis beginning in Feb. 2004.

ESP Core Research

Summary Comments: The review panel's feedback on core ESP research activities was very supportive and complimentary in all three areas (feedstock variability, pretreatment, and enzymatic hydrolysis/process integration). In particular, the feedstock variability work should continue but be coordinated with DOE collection and storage work. One participant stated that corn is not bred for high quality corn stover and was skeptical of the value of continuing investigation of corn stover viability. The panel recommended continuing efforts in high solids pretreatment as well as continuing to supply process materials to interested stakeholders. Saccharification and process integration work should continue focusing on process design, high solids saccharification, and contamination issues using a model feedstock and fermentation process.

Responses:

- We will continue our core research activities in feedstock variability, pretreatment, and process integration. Research plans will be tied to goals in the MYTP. Specific elements of the future plans are discussed below in the Future Directions section.

- We believe that corn breeders are interested in producing corn with specific compositional characteristics, such as high cellulose content, which correlate with a desirable harvest property and are also a desired properties for a feedstock intended for conversion to sugars.

Process Analysis

Summary Comments: The review panel supported continuing life cycle work with NREL coordination; however, industry should be supplying the bioconversion process information. The reviewers supported continuing process-engineering work relevant to determining research direction, but were less supportive of the value of continuing efforts in risk analysis and linear programming. One participant found Monte Carlo-based risk analysis useful and suggested continuing this work.

Responses:

- We will continue the life cycle analysis work and will explore the possibility of using industry bioconversion process data, however, to make the work publicly available we may need to use results from NREL process models.

- We will continue to improve our process engineering models to provide guidance to both Biomass Program management and researchers. Risk analysis and linear programming models are valuable tools to improve our understanding of the technology and we propose continuing this work, although they will not be an effort in the ESP project.

Future Directions

Summary Comments: The primary concern of the reviewers and other audience participants was that our activities be crosscutting and non-competitive to industry efforts. A specific suggestion from the review panel was that NREL should coordinate and monitor efforts in understanding feedstock issues. Other suggestions for future project work included assembling and interpreting feedstock compositional information, generating and characterizing process effluents, understanding recycle streams and process stream rheology, developing data on separate C6 and C5 fermentations, testing solid-liquid separation, and understanding the use and properties of specific plant components (e.g., cobs) all relevant process integration issues.

Responses:

- We will continue to look to a broad range of industries for guidance when planning future activities related to the ESP project and will expect industry to suggest activities that are crosscutting and non-competitive. Of necessity, we have selected a model feedstock (corn stover) for this work and will select a model conversion system that is able to convert a large fraction of biomass to a representative product (ethanol).

- Multi-laboratory work on feedstock issues is being included as part of the MYTP and FY04 AOP for DOE's Office of the Biomass Program and is being fostered by activities being conducted mainly at ORNL and INEEL. The goal of this work is to develop sustainable technologies capable of supplying lignocellulosic biomass to a biorefinery. However, ESP's effort will focus on understanding the genetic/environmental factors affecting corn stover variability.

- We have an ongoing effort with the ASTM Biomass characterization task to standardize methods for measuring and reporting biomass compositional data. The need to measure and characterize other feedstocks will be evaluated with input from industry.

We will also continue our work characterizing corn stover compositional variability and developing wet chemical and rapid analysis methods to support the developing industry.

- Specific work elements suggested by the reviewers are considered below. Generating and characterizing representative process effluents is being included in the MYTP, which of necessity will also include understanding and characterizing recycle streams. Also as part of this effort we need to identify a model conversion process that may also involve testing of separate C6 and C5 fermentations. Plans are to generate representative process samples for combustion and wastewater testing by mid-2005. Process stream rheology characterization is being done as part of a larger effort by researchers at the University of Louisville to understand hydrodynamics in pretreatment and bioconversion reactors. Near-term plans are to better characterize the options for solid/liquid separation for pilot plant as well as commercial scale operation. As part of this effort, we will test a PneumaPress pressure belt filter solid/liquid separator, which is the leading candidate equipment for separating and washing pretreated biomass slurry streams. Other solid/liquid separation equipment may also be tested as new needs are identified. Characterization of specific corn plant anatomical fractions will be a new activity starting in FY04, but will be conducted outside the ESP project.